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STUDIES FOR STUDENTS

A CENTURY OF PROGRESS IN PALEONTOLOGY

THE presence of fossils in the rocks was observed by the ancient priests of Egypt, by the Brahmans of India, and by many other ancient peoples. In some cases the bones of gigantic mammals, such as the mammoth and mastodon, were observed, and, being considered as human bones, they gave origin to many of the beliefs in the existence of races of giants. The Greeks and Romans also observed fossil shells, bones, and plants, and some of their philosophers speculated as to their origin, although little or no progress was made in their study. Some of these men believed that the shells found preserved in strata far inland were really the shells of once living animals, while others, with Theophrastus, "supposed them to be produced by a certain plastic virtue latent in our earth."

It was not until the early part of the sixteenth century that geologic phenomena began to attract the attention of the Christian nations. At that period an animated controversy sprang up in Italy concerning the true nature and origin of marine shells and other fossils found abundantly in the strata of the peninsula. In the year 1517 extensive excavations were made in Verona, which brought to light a multitude of curious petrifactions, and furnished matter for speculation to different authors. Among these was Fracastoro, who declared "that fossil shells had all belonged to living animals, which had formerly lived and multiplied where their exuviæ are now found." He exposed the absurdity of having recourse to the plastic force of Theophrastus, which had power to fashion stones into organic forms, and also demonstrated the futility of attributing the situation of the shells in question to the Mosaic deluge, a theory that was obstinately defended by some. Fracastoro, however, had but few companions in his clear and philosophical views, and for nearly three centuries two simple and preliminary questions were vigorously discussed — (1) whether fossil remains ever belonged to living creatures, and (2) whether, if this be admitted, all the phenomena could not be explained by the deluge of Noah.

Throughout all this long controversy regarding the nature and origin of fossils, little was done in the way of description of fossil forms; but with the reformation of the system of nomenclature by the introduction of the binomial system, instituted by Linnæus during the latter half of the eighteenth century, the way was opened for a more accurate description of fossils than had been practicable previously. Linnæus himself described and named some species of Silurian fossils from Sweden, among which may be mentioned the well known and widely distributed *Atrypa reticularis* and *Halysites catenulatus*, although the genera in which these species are now placed are of later date.

The real scientific study of fossils may be said to have begun with about the opening of the present century. William Smith (1790), in England, had recognized the value of the fossil contents of the rocks in tracing the strata over extended areas, but he did not devote his time to the description and naming of the fossils which he found. At about this same time rich stores of beautifully preserved fossils were discovered in the immediate neighborhood of Paris. The labors of Cuvier and Brougniart upon the vertebrates, and of Lamarck upon the fossil shells of this area, constitute some of the earliest really scientific investigations of fossil organisms. In fact, it may be said that Cuvier laid the foundation of the science of paleontology, when in 1797 he called attention to the fact that elephant bones discovered in the Paris basin were different from the bones of living species, and thus drew a distinction between living and extinct animals as implying present and past groups of living organisms.

Many of the works on paleontology published in the early part of the present century exhibited little or no attempt at classification of the materials described. The classic work of James Sowerby, entitled " Mineral Conchology," which was published in seven volumes, the first of which bears the date 1812 on the title-page, and the sixth 1829, a work in which very many of the species of British fossils were originally described, may be taken as a type of this group of works. In the arrangement of the matter included in these volumes no attempt is made at classification, either zoölogically or according to the geologic horizons in which the fossils were found. It is simply a paleontologic scrapbook, as it were, of descriptions and illustrations of fossil species. One plate, with its accompanying descriptions, may be devoted to Tertiary gastropods, the next to Paleozoic brachiopods, a third to Cretaceous ammonites, a fourth to Tertiary gastropods again, and so on, the total number of plates in the whole work being 648.

Following the early period in which there was to a great extent an absence of classification, the classification of fossils gradually developed along two distinct lines. On the one hand, with the increase of knowledge and with the progress in taxonomy of living organisms, the zoölogical classification of fossils made rapid strides, and many orders, families and genera founded wholly upon fossil forms were established, and were fitted into the scheme of classification of all organisms, making it far more complete than it could ever have been made from the study of living organisms alone. On the other hand, there grew up a classification of fossils into faunas, so that a whole series of extinct faunas, from the earliest Paleozoic time to the recent, were recognized. It also gradually came to be established that the sequence in time of extinct faunas, in their larger characteristics, was the same for all parts of the world where fossils were found.

For many years these two systems of classification of fossils went forward hand in hand, but with the development of the science the two paths along which progress was being made became more and more divergent, until at the present time the two divisions of the subject have become fully differentiated.

It is of interest to trace the differentiation of these two lines of progress in the life work of such a paleontologist as the late James Hall, whose career extended over more than half a century.

In the earlier volumes of the paleontology of New York, the faunal classification of fossils is predominant. Many new species and genera are described as members of the faunas under discussion, there being no elaborate investigations into the natural taxonomic grouping of organisms. In volume four of the work we begin to see the deviation of the line of investigation toward the biologic side, the faunal grouping being made subordinate to the taxonomic. This same subordination is seen in volumes five, six, and seven, while in volume eight we find the faunal classification entirely displaced, and the whole volume devoted to the treatment of the genera of Paleozoic brachiopods. We have, therefore, in this series of volumes an exhibition of the development of the science as illustrated by the life work of one man, from the faunal classification in 1847, through the mixed faunal and biologic, to the purely biologic classification in 1894.

This differentiation of the science, which has become nearly accomplished at the present time, is well exhibited in the character of the paleontologic monographs which have been published during the past decade or less. On the one hand such works as Wachsmuth and Springer's monograph of the "Crinoidea Camerata," a work which is strictly biologic in its treatment of this extinct order, is an illustration of one division of the subject, and on the other hand may be mentioned Walcott's "Fauna of the Olenellus Zone," where the biologic treatment of the fossils is made entirely subordinate to their faunal associations.

While these two branches of paleontologic science have been differentiating, the older method of investigation has by no means disappeared, and during this whole century of progress there have been appearing constantly contributions to paleontology of the "scrapbook" order. Among the more recent of these made upon a large scale may be mentioned the series of bulletins which have been issued from the Illinois State Museum of Natural History during the past decade. In these contributions some hundreds of species have been described, belonging to various classes and orders of organisms and from various geologic horizons, but they have contributed little or nothing either to the taxonomy of the subject or to the faunal relationships of the fossils described. Such work, however, is valuable even today in so far as it is accurately done, because it relieves the investigator in the more special lines of research from a vast amount of labor. Every species of fossil must have a name as a sort of handle by which it may be manipulated, but with the more special workers in the subject, the description of species and the giving of names is but a means to an end, the discovery of new species not being the ultimate result sought after.

The biologic division of paleontology consists of the study of the structure and organization of individuals, of their ontogenetic development, of the relationship of species to species and of genera to genera, and of their phylogeny, all with the ultimate end of establishing as nearly as possible a natural classification of all organisms. A large proportion of all the work being done today among fossil vertebrates comes into this category. Among the invertebrates much work of a high order is also being accomplished. The recent contributions by Beecher upon the structure, ontogeny, and classification of trilobites and of brachiopods may be mentioned, also the contributions by Hyatt and others upon the cephalopods.

The faunal study of fossils is intimately connected with geology, in fact no history of the earth, from the period beginning with Cambrian time, can be made complete when the life history is excluded, and for this reason this faunal study of fossils is coming to be called paleontologic geology. Instead of taking a single species or any taxonomic group as the unit of study, as is done by the biologist, organic societies, those organisms which lived in a single locality under similar environment during a limited period of time, are the subjects of investigation. The fossil societies or faunas are dissected into their various elements, their relation to the environment in which they existed are studied, their relations to neighboring societies or faunas, both in time and space, and their migrations are the subjects of investigation. The study is a history of organisms in its broadest sense, and it is just as truly an historical study as is the study of human history. In fact many parallels may be drawn between this history of faunas and the history of the races of men.

Those organisms which are preserved in the sedimentary rocks, and among which our historical investigations may be carried on, are to a large extent the marine organisms which inhabited the shallow seas which have existed in past time upon the continental platforms, both on the borders and in the interiors of the continents. The life of the dry land, that of the fresh waters, and the aërial life, cannot have been preserved except under exceptional conditions. The ancient life of the abysmal depths of the oceans is unknown to us because of the entire, or at least approximate, absence of abysmal sedimentary deposits upon the continents.

Among the earlier geologists of the century, whose individual observations were limited to comparatively small geographic areas, at a time when the literature of geology and paleontology was but limited, the notion grew up that identity of fossil species and identity of age of the strata containing the fossils always went together. But gradually, with the increasing knowledge of living marine organisms, especially of their geographic distribution into more or less distinct provinces limited by physical conditions such as temperature, depth, ocean currents, purity of water, etc., and with the broadening knowledge of fossils themselves, when it came to be realized that the same organisms did not live everywhere at the same time in the past, but that, as now, there were also during all geologic time distinct zoölogic provinces inhabited by distinct faunas, and, furthermore, that these provinces were constantly changing their geographic boundaries, then the task of accurate or even approximate correlation of strata over any great distances from their fossil contents seemed to become almost hopeless. Indeed, so hopeless did the task seem to some that in 1862, in his presidential address before the Geological Society of London, Huxley[1] said: "For anything that geology or paleontology are able to show to the contrary, a Devonian fauna and flora in the British

[1] Q. J. G. S., Vol. XVIII, p. 46.

Islands may have been contemporaneous with Silurian life in North America and with a Carboniferous fauna and flora in Africa. Geographical provinces and zones may have been as distinctly marked in the Palæozoic epoch as at present, and those seemingly sudden appearances of new genera and species, which we ascribe to new creation, may be simply results of migration."

It was doubtless due to this seemingly more or less chaotic condition of the geographic distribution and the geologic range of fossils, that the majority of the students of extinct life during the latter part of the century have turned their attention to the biologic rather than to the geologic problems involved; but these very investigations which the biologists have made have materially assisted the paleontologic geologist in his researches. The biologic paleontologist may, and often does, carry on his investigations and make valuable contributions with little or no knowledge of the geologic phases of the science save the more or less dogmatic assertions of text-books. But the paleontologic geologist must of necessity follow closely the results of his biologic brother, though his own investigations may be something entirely different. In fact, the perfection of the taxonomy of fossils is to the paleontologic geologist but one of the means to an end, and not the ultimate end sought. The two divisions of the science may be compared with the ancient and the modern methods in the study of human history. The biologic division may be compared with the older method of historical study, in which the lives of a few conspicuous characters monopolized the whole study. On the other hand, the investigations in paleontologic geology may be compared with the modern scientific study of history, in which the evolution of society is made most prominent, the conspicuous characters being considered as the results of social conditions rather than as their causes.

At the present time it is believed by most, if not all, geologists and paleontologists that the great geologic systems represent practically the same time-periods throughout the world. It is also believed by many that the limits of the recognized geologic periods, in so far as they are really natural divisions of geologic time,[1] are practically contemporaneous. It is also believed that about three divisions in each period may be usually detected with much certainty throughout the world, although the constitution of the faunas may vary to a considerable degree.

It becomes the task of the paleontologic geologist to investigate the fossil faunas, the organic societies of past time. Through a study of the geographic distribution of species and genera and their relationships to preceding and succeeding forms, the approximate limit of the zoölogic provinces of past time are determined, and from these data approximate restorations of the ancient geography are made. From a study of the changing physical conditions and the changing faunas are determined the migrations which we now know to have taken place and which Huxley suggested as a cause of sudden changes of fossil faunas.

Among fossil faunas as a whole there are two conspicuous types, (1) the cosmopolitan faunas and (2) the provincial faunas. At different periods of the earth's history these two types of faunas have been dominant. During Silurian time, for instance, there seems to have been in existence a great cosmopolitan, shallow-water, marine fauna, which is represented in America, in Europe, in Australia, and New Zealand, and probably will be discovered also in the other continents. The conditions for the development of such a fauna seem to have been the presence of widespread, shallow seas upon the continental platforms, epi-continental seas, as they have recently been called.[2] With broad seas of this sort around the borders of the continents, and extending into the interior by means of great tongues or lobes, and with conditions approximating base-levels upon the land, there would be a great limestone forming epoch, and with the probable atmospheric conditions of such an epoch[3] the temperature conditions upon the earth would be far more nearly equable than they are today, so that the same species could live both in the tropics and in the polar regions, as the distribution of the fossils indicates to have been the case. Under such conditions the shallow-water marine organisms would have the most favorable opportunity for intercommunication with all parts of the world, and there would be developed just such a cosmopolitan fauna as we know existed in Silurian time.

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[1] See "The Ulterior Basis of Time Divisions and the Classification of Geological History," by T. C. CHAMBERLIN, JOUR. GEOL., Vol. VI, p. 449.

[2] JOUR. GEOL., Vol. VI, p. 602.

[3] JOUR. GEOL., Vol. VI, p. 609.

The Devonian period gives us a good illustration of the provincial type of faunas. During this period the shallow-water marine faunas exhibit a great diversity in various parts of the world. The Devonian faunas in New York, or even in southern Illinois, have less in common with those of Iowa, than have the Silurian faunas of the interior of North America with those of Europe or even with those of Australia. The Devonian faunas of Europe are also different from the American, and, furthermore, they differ among themselves. In South America and other parts of the earth there are still other types of Devonian life. The evidence afforded by the distribution of species and genera indicates without a doubt that the provincial development of faunas was one of the most conspicuous characteristics of the period. This type of development was, of course, brought about by the greater or less isolation of great shallow-water tracts in different parts of the world, in each of which the evolution of the life progressed along its own peculiar lines, molded by the particular environmental conditions which obtained in each tract or province.[1] Because of the more or less complete isolation of these various provinces, and the absence of shallow-water paths along which intercommunication between distant parts of the earth was possible, the development of a cosmopolitan fauna such as existed in Silurian time was out of the question.

In addition to the provincial development of the Devonian faunas, the life history of the period is complicated in a still further degree by reason of the continuous changes in the geographic limits of the provinces themselves. The major development of the several great Devonian provinces was, in all probability, in shallow seas upon the borders of the continents, and the more important changes in their areal distribution was probably due to the cutting away of barriers formed by the more or less elevated rim of the continents, and the extension of lobes of the sea into the interior, so forming interior epicontinental seas. It is in the sediments of these interior epicontinental seas that the greater portion of all our Paleozoic life records are preserved. The borders of the continents are the chief regions of disturbance during periods of dynamic activity, so that the records of the life in the normal border provinces of such a period as the Devonian are to a great extent destroyed.

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[1] See "A Systematic Source of Evolution of Provincial Faunas," by T. C. Chamberlin, JOUR. GEOL., Vol. VII, p. 597.

If we were able to possess ourselves of sufficient data in regard to the border provinces, it is probable that no sharp life breaks would be found, but in the interior epicontinental seas, the case is very different. By the slow cutting away by erosion of the barrier rim, or by the local sinking of the land, communication is established successively between the interior seas, and first one and then another of the great border provinces, and there are successive incursions of very different faunas, which make their appearance in the interior very suddenly, although their evolution has been in progress in some border province during a long lapse of time. As an illustration of such a sudden appearance of a fauna into an interior epicontinental sea, the fauna of the Corniferous in eastern North America may be mentioned. This fauna with its large number and variety of corals, its great number of cephalopods including the first goniatite, and, most of all, the host of armored fishes, appears with comparative suddenness, probably from the north through Hudson Bay, and includes many organisms which could not possibly have been derived from the preceding Devonian faunas, the Oriskany and Helderberg. The evolution of this fauna had probably been in progress during all the preceeding time since the Silurian in its more or less isolated province, but its appearance in the interior epicontinental sea of Devonian time in eastern North America was relatively sudden.

Such a sudden appearance, in a series of sedimentary rocks, of a new fossil fauna, with apparently no genetic predecessors in the immediate region, may be compared with the sudden appearance in North America during the sixteenth century of the advanced culture and civilization of Europe among the savage tribes which had occupied the continent previous to that time. Although the appearance in America of the white man with his advanced culture was sudden, and his influence spread so rapidly that it soon drove into practical extinction the preëxisting and less advanced culture of the Indian, it was really the culmination of a long and gradual development, in Europe, of the art of building and sailing ships. In a similar way the sudden appearance of a new fossil fauna in a series of sedimentary rocks may be but the culmination of some physical change which has been in progress during an extended period of time. The submergance or the erosion of a land mass may be slow, and may continue through a long lapse of time, but the culmination of the phenomenon will be when the land passes below sea level, thus removing a barrier and allowing the immigration of a marine fauna into a region previously occupied by a very different assemblage of organisms. The conflict following such an immigration may be compared with the conflict between the Indian and the European cultures in America.

The resulting fauna from any such incursion and mingling within an interior sea, as has been described above, will of course be different from either of the original faunas. The Corniferous fauna in eastern North America, in addition to that element which came in from the outside, contains also an element which may be traced directly back to the preceding Oriskany or Helderberg faunas which had inhabited the same region. When the German tribes made their incursions into the Roman Empire, bringing in a new culture, the old Roman civilization and culture was not entirely destroyed, but there was built up a new civilization and a new culture, differing from either the Roman or the

German, which included elements from each. In the same way a resultant fauna, formed by the mingling of two or more faunas, will contain elements from each which can be detected by a careful study and dissection of the entire assemblage of organisms.

In general, the species in any fossil fauna fall into one of two categories: (1) indigenous evolution species, or those whose ancestors have lived in the same region and whose evolution has there taken place, and (2) immigration species whose ancestors have lived in some other geologic province and whose sudden appearance in the fauna under consideration is due to an immigration from the outside. It is the work of the paleontologic geologist to investigate each species of the fauna he may be studying, to determine in which category each belongs, and in the case of the immigration species to determine in what part of the world or in what geologic province its previous evolution has taken place, and what are the probable paths of migration.

In the historical study of fossil faunas it is interesting and suggestive to draw parallels with the history of human races. Until comparatively recent times there has been a remarkable provincial development of the races of men. Among the more primitive peoples a range of mountains or a great river was a sufficient barrier to prevent migration, because, as in the case of the provincial faunas, they had not means at hand for intercommunication between the separated provinces. But there has been a gradual development among the human races, of means of communication, first by beasts of burden and later by mechanical devices, until today, through the agency of the great ocean steamers, the transcontinental railways, and the telegraph, no corner of the inhabitable earth can be said to be isolated. With the increased facilities for intercommunication, there is being developed a great cosmopolitan human race, which will in time inhabit the whole earth, just as in far-away Silurian time there was developed, by reason of the widespread shallow waters upon the continents, a cosmopolitan fauna which reached from North America to Australia.

The questions involved in this faunal history of the earth are complicated, but the fossils imbedded in the rocks are the data, and these are far more indisputable than are the data upon which ancient human history is being built. A recent writer gives the following definition of ancient history:[1] "A confused jumble of traditions, distorted to suit special pleaders; then rejumbled, and mixed, and confused, and redistorted according to the design of each new writer—the story of noble actions of big-minded men recast in the crucible of petty intellects, untrained in public life and unfit to grasp even the commonplace—the story of petty actions seized upon by enthusiasts and exalted into a nobility which would have been beyond the recognition of the original actors—all sorts of stories attempted to be told by weak, incapable men without purpose, or by unconscientious men or wilful liars with a purpose—obscure acts twisted into curious shapes in the brains of industrious writers—truth taken by well-meaning men and so changed by ignorance and lack of comprehension and unfitness to judge that it loses all semblance of its original self and becomes a misshapen, irrecognizable, utterly twisted and contorted thing, without much more than a vestige of fact upon which it is supposed to be based. This is ancient history." If the human historian is able to build up a story of the human race from such data, how much more certainly will the paleontologic geologist, by diligent study and investigation of his absolutely indisputable data, be able to build up a creditable history of the life of the earth since Cambrian time.

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[1] JOHN BRISBEN WALKER, in The Cosmopolitan, March 1899, p. 476.